The Use of the Arduino Embedded System as a Prototype of a Mobile System Controlling a Person's Breathing Using a Sensor Printed on a T-shirt

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Abstract— **The aim of this idea is to show an early stage draft for measuring the electrical resistance in a designed/elaborated textile printed sensor with a mobile Arduino microcontroller. The textile sensor was developed by the screen printing technique based on a water dispersion of carbon nanotubes printing composition. By stretching and squeezing the T-shirt during breathing, we change the electrical resistances of the printed sensor. The measured resistance corresponds to the number of breaths of a person wearing it. The microcontroller can calculate the number of breaths as a number of electrical resistance peaks which can lead to monitoring human live parameters.**

Keywords - textile actuator; t-shirt; textronic; monitor; microcontroller; Arduino; human body; carbon nanotubes; screen printing; printing composition; textiles.

I. INTRODUCTION

Manufacturing textronic systems is not an easy task. In order for the garment to meet certain properties, it is necessary to pay attention to a number of factors. When creating a design of clothes, one cannot forget about the requirements that accompany electronic products (including accuracy, measuring range), the behavior of the selected textile products (including low weight, flexibility), as well as the applicable principles of materials science and automation. The proper selection of textiles and electronic systems as well as their mutual integration is a big challenge for scientists. With the increase in technology development, the quality of manufactured systems has improved. Textronic products are created mainly using everyday clothes by combining them with a miniaturized electronic system, sensors, and a power supply system.

The creation of textronic systems is possible due to the use of sensors. The characteristic properties of some raw materials from which textile products are made include piezoelectric and electrostatic properties, as well as shape memory. Materials using these features are called intelligent and they combine the functions of both the sensor and the activator.

The most common sensors are sensors that provide information in one of the electrical quantities, such as voltage, current, and electrical resistance. This is due to the fact that electric current is a signal that is easily amplified, transmitted over long distances, further processed using digital techniques and computers, and saved. Their properties change under the influence of an external stimulus, which may be e.g. a mechanical stimulus or an electrical impulse.

Several research works [4]-[8] conducted at the Institute of Material Science of Textiles and Polymer Composites in Lodz, Poland, showed a real possibility of creating flat fiber products with sensory properties containing carbon nanotubes. The aim of the presented work is an early stage draft for measuring the electrical resistance of the designed/elaborated printed textile sensor on the chest part of a garment [6][8], using a mobile Arduino microcontroller. The measured electrical resistance corresponds to the number of breaths of a person wearing it. The Arduino microcontroller can calculate the number of breaths as a number of electrical resistance peaks.

The rest of the paper is structured as follows. In Section II, we present the state of the art in the topic of sensors controlling human live parameters. In Section III, we present the practical measurement and aim of calculations we may follow. Finally, we conclude the work in Section IV.

II. STATE OF THE ART

The idea of using Arduino is not new [1]. [1] describes the LilyPad Arduino, a fabric based construction kit that enables novices to design and build their own soft wearables and other textile artifacts. An assortment of sensors and actuators elements can be sewn to cloth substrates and each other with conductive thread to build e-textiles. In [2], the authors investigate aspects regarding the use of wearable electronic sensors, embedded in clothing for monitoring the health using simple electronics such as Arduino board to perform signal analysis processes. In [3], there is a breathing rhythm and an electrocardiography (ECG) measured using flexible substrates on a T-shirt with bi-axial accelerometers involved. The work in [3] is a slightly similar to ours, but ours is much easier to do and simpler to use in everyday life.

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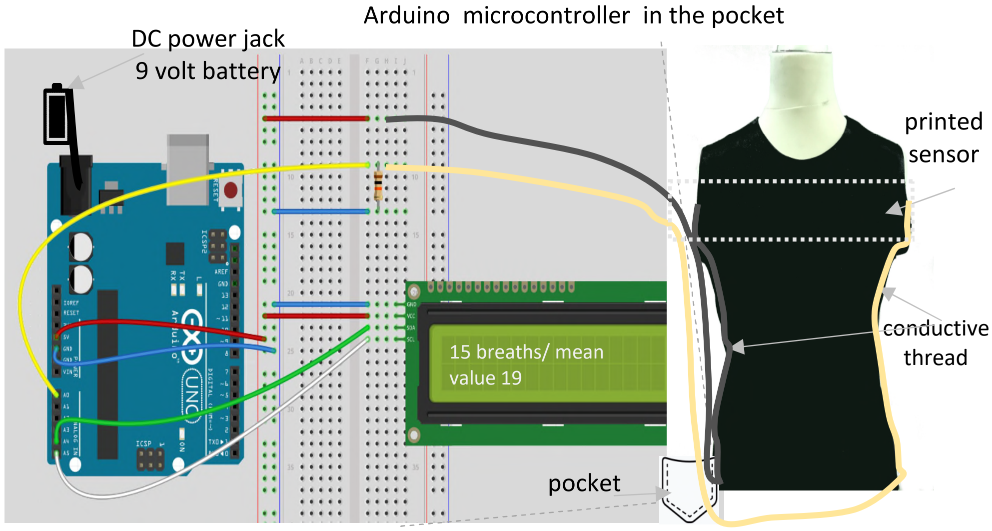

Figure 1. The microcontroller and textile sensor connection diagram – (own study, Arduino graphics taken from [10])

III. PRACTICAL MEASUREMENT

A. Research apparatus

- Arduino or Genuino Board connected to measuring electrodes,
- T-shirt with print containing sensors receiving and transmitting information about the tested subject [4].

B. Idea of research

The aim of the research is to measure the electrical resistance with the Arduino microcontroller [9][10] of an elaborated textile sensor for changes of electrical resistance during normal activity of a human who is wearing a T-shirt. The number of breaths may be calculated by the logic inside Arduino by counting the picks of resistance within 60 seconds. An exemplary architecture diagram is showed in Figure 1. We will use two resistors: the first resistor is 10k Ω and the second is represented by the textile sensor. From the point of view of Ohm's law, it is important that the resistors are connected in series. The resistor with a known resistance of 10k Ohm is between the ground and the cable connected to the A0 pin, while the tested textile sensor resistor is between the cable connected to the A0 pin and 5V from Arduino.

According to Ohm's law, the current flowing in the system is the quotient of voltage and resistance of a given system.

$$I = U / R \qquad (1)$$

where I is the current, U is the voltage, and R isthe resistance.

Our system consists of two resistors connected in series with values that we will denote by R1 and R2. R1 will be our known resistor, while R2 will be a textile sensor. Current I flows through the system. Such current flows through both R1 and R2. The voltage drop is in the whole system and in each of the resistors the voltage changes proportionally to its value. The voltage that falls on the whole system is the voltage taken from Arduino, i.e., 5V - we will denote it as U. Having the above in mind, we can determine the following formula:

$$U / (R1 + R2) = U1 / R1 \qquad (2)$$

$$R2 = ((R1 * U) / U1) – R1 \qquad (3)$$

where R1 is the known resistor 10k Ohm and R2 is the resistance of the textile sensor.

Formula (3) may be calculated inside the microcontroller. The values can be stored in the Arduino memory for 60 seconds interval. An average value of peaks, corresponding to the number of human breaths, may be calculated and displayed on the LCD. By normal breathing, we perform the change of the textile sensor electrical resistance, we change the value of resistance which is connected to the center pin of the resistor series. This changes the voltage at the center pin. This voltage is the analog voltage that we will read as an input by the A*nalog-to-Digital Converter (ADC)*. In case of difficulties with the calculation of the number of peaks, we may add a derivative element between the textile sensor at A0 pin and 5V power pin. The potential use of internal timer may make the calculations easier. It all depends on how the measurements proceed.

IV. CONCLUSIONS

Works currently carried out by the authors allow to state that it is possible to measure breaths of humans by using a T-shirt textile sensor. The authors are aware of the challenges of changing human body size, ambient humidity, temperature, pH of sweat, and the related need to calibrate the sensor in various atmospheric conditions.

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As future work, first, we will work on miniaturization, even by removing the LCD and the big battery, and adding a Bluetooth module. Secondly, we will build a mobile Android app to present the data on the smartphone.

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